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SIGNIFICANT SOLAR PROTON EVENTS, 1955-1969.(U)
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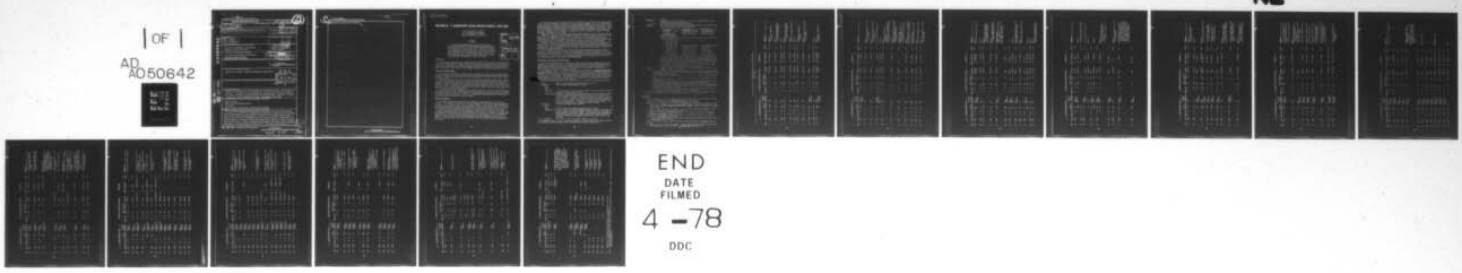

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A list of the significant solar proton events for the period 1955 through 1969 has been prepared with identification limited to events with solar proton induced absorption as measured by a riometer in the earth's polar caps. A total of 139 events were identified over this 15-year period. This table was compiled after a thorough search of primary data sources in order to ascertain an onset time, a time of maximum absorption, the value of the maximum absorption, and the duration of each event. The observing location is → next page

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identified for each of the events.

SECTION III - 4. SIGNIFICANT SOLAR PROTON EVENTS, 1955-1969

M. A. Shea and D. F. Smart
Air Force Geophysics Laboratory
L. G. Hanscom Air Force Base
Bedford, Massachusetts, 01731, USA

ABSTRACT

A list of the significant solar proton events for the period 1955 through 1969 has been prepared with identification limited to events with solar proton induced absorption as measured by a riometer in the earth's polar caps. A total of 139 events were identified over this 15-year period. This table was compiled after a thorough search of primary data sources in order to ascertain an onset time, a time of maximum absorption, the value of the maximum absorption, and the duration of each event. The observing location is identified for each of the events.

INTRODUCTION

At the request of researchers correlating possible solar-terrestrial effects with meteorological observations we have compiled a table of significant solar proton events observed at the earth for the period 1955 through 1969. In an effort to make a reliable and self-consistent list we included only those events for which there was enhanced ionospheric absorption as measured by a riometer in the earth's polar caps. These events are those commonly referred to as "polar cap absorption" (PCA) events.

POLAR CAP ABSORPTION EVENTS

Polar cap absorption events are identified by the presence of enhanced radio wave absorption in the polar ionosphere. Over the years the detection of this enhanced absorption (and hence the identification of a PCA event) has been made by various techniques such as f-min, f-fix, VLF, VHF, and riometer observations.

Unfortunately the detection of polar cap absorption does not necessarily indicate that a significant solar proton event has occurred. Even when the identification of polar cap absorption can be unambiguously associated with the influx of solar particles, it is extremely difficult to compare the magnitude of different events detected by different techniques except in a general manner such as weak, strong, or blackout. Furthermore, we now know that an event in which the electron flux is large produces more medium and high frequency absorption than would be expected from a direct measurement of the proton flux or from a riometer measurement.

In compiling this list of significant solar proton events we have included only polar cap absorption events detected by riometer measurements, the riometer being the only sensor existing throughout the 19th and 20th solar cycle and also capable of making quantitative measurements which can be directly related to solar particle fluxes. Even with this limitation, care must be taken in utilizing riometer measurements to compare one event with another.

RIOMETER MEASUREMENTS

The riometer measures the absorption in the intensity of cosmic noise generated by stellar sources; if the ionization increases above the local observing site then the signal being received is attenuated. The riometer was shown to be an efficient detector of solar proton induced ionization in the lower ionosphere (Bailey, 1964; Little and Leinbach, 1959; Reid and Leinbach, 1959) with the measured riometer absorption approximately proportional to the square root of the particle flux above a specified energy (Adams and Masley, 1965; Bailey, 1964; Potemra, 1972; Van Allen, et al., 1964).

Riometer measurements are local time dependent. While the effect of the solar zenith angle can be minimized during the daylight hours when the ionosphere is sunlit, the response of a riometer when the ionosphere is in darkness is drastically different. We have tried to utilize only riometer measurements through a sunlit ionosphere in compiling the event table; however, it is possible that during the early 19th solar cycle, particularly during the northern hemisphere winter, some of the smaller polar cap absorption events were not identified since there were no riometer measurements in the Antarctic.

Solar proton access to the earth's polar caps is dependent on the anisotropy of the solar protons in the interplanetary medium, the direction of the interplanetary magnetic field, and the geomagnetic cutoff rigidity of the detector location. For examples see the discussion by Paulikas (1974). A combination of particle anisotropy and the interplanetary magnetic field direction can result in factors of two differences in the measured proton flux between the northern and southern polar regions. In addition the geomagnetic cutoff rigidity of solar particles (thereby establishing a lower energy limit below which particles cannot be detected at a specific location) is dependent on magnetic latitude, geomagnetic conditions, and local time.

Ideally the riometers used to detect solar proton events should be located in the deep polar cap (i.e. poleward of the auroral zone) to minimize the effects of absorption caused by particles precipitating out of the magnetosphere such as aurora, relativistic electron precipitation events, etc. Unfortunately many riometers are located in the auroral zone (e.g., at College, Alaska and Kiruna, Sweden) where the local magnetospheric effects can contribute to the total ionization, thereby leading to the possibility that the inferred solar particle flux may be considerably over estimated.

During the first part of the 19th solar cycle (1954-1957) very few riometers were located in the deep polar cap. For this time period it was necessary to utilize the riometer data available from College, Alaska or from the VHF measurements that Bailey (1964) converted to equivalent riometer events for Churchill, Canada. As the 19th solar cycle progressed, additional riometers were installed in the deep polar cap in both hemispheres.

In the compilation of the solar proton event table a preference has been given to the data recorded by the 30 MHz* riometers at Thule, Greenland, Shepherd Bay, Canada, and McMurdo, Antarctica, whenever these data were available. In many cases publication of the riometer measurements for specific periods were utilized; however, we did not scale any of the original records since corrections for the quiet day curve and for the mid-day recovery must be made to the original data before details of a solar induced polar cap absorption event can be ascertained.

DESCRIPTION OF THE SOLAR PROTON EVENT TABLE

The table of significant solar proton events includes three major parts summarizing the onset, maximum, and duration of each event. In all cases we have tried to give the earliest onset time, the highest maximum absorption value and the longest duration derived from riometer measurements. For some events, two entries have been given if the earliest onset time, highest absorption value or longest duration were observed at different locations.

In compiling this table we utilized the data originally assembled for the Catalog of Solar Particle Events 1955-1969 (Dodson, et al., 1975). In some cases the availability of additional data or a reevaluation of the original data sources has resulted in differences between the values given in the "Catalog" and the values given in the accompanying table. In these cases, the values in this table supercede those in the "Catalog". Persons interested in other aspects of solar particle events, such as measurements of solar particles by satellites, the associated solar phenomena, radio emissions, X-rays and references are referred to the "Catalog".

The table of significant solar proton events consists of 15 columns of information as follows:

Column 1: Number of event, numbered chronologically from 1 to 139.

Columns 2-6: Date and onset time information as follows:

- Year
- Month
- Day
- Onset Time: In universal time. If the exact time is known this value is given; otherwise values to the nearest hour are given.
- Location and/or Technique: If the onset data are from Bailey's list of PCA events (Bailey, 1964) determined from VHF measurements and converted to an equivalent riometer absorption at Churchill, Canada, the notation VHF is given. If the onset data are from a riometer, the location followed by the word "riometer" is given. In most cases the values under the maximum and duration of the event are from the same riometer. Exceptions are noted under the "Comments" column if the event information is a composite from several sources.

Columns 7-11: Maximum of absorption event as follows:

- Month
- Day
- Time: Universal time of the maximum absorption during the event.
- Absorption (dB): Value of the hourly average maximum absorption, in dB, for the time in the previous column. The VHF measurements have been converted to equivalent riometer absorption at Churchill, Canada. Care should be taken when comparing the maximum absorption from a riometer located in the auroral zone such as College or Kiruna with the maximum absorption from a riometer deep in the polar cap.
- Location: The location at which the maximum absorption was measured

* It is common practice to refer to the riometer frequency as 30 MHz; however, the frequency actually is 27.6 MHz with a 100 KHz frequency sweep to minimize radio frequency interference.

Columns 12-13: Duration

Hours: The duration of the event in hours. A "C" in this column indicates the absorption continues into the next event.

Location: The location of the event with this duration.

Column 14: PEC. The notation PEC stands for the three digit proton event classification as defined by Smart and Shea (1971) as follows:

First digit		Second digit	Third digit
Digit	E >10 MeV Satellite measured proton intensity $cm^{-2}sec^{-1}ster^{-1}$	Daylight polar 30 MHz riometer absorption	Sea level neutron monitor increase
-3	From 10^{-3} to 10^{-2}	-	-
-2	From 10^{-2} to 10^{-1}	-	-
-1	From 10^{-1} to 10^{0}	-	-
0	From 10^{0} to 10^{1}	No measurable increase	No measurable increase
1	From 10^{1} to 10^{2}	Less than 1.5 dB	Less than 3%
2	From 10^{2} to 10^{3}	From 1.5 db to 4.6 dB	From 3% to 10%
3	From 10^{3} to 10^{4}	From 4.6 db to 15 dB	From 10% to 100%
4	Greater than 10^{4}	Greater than 15 dB	Greater than 100%

The first digit represents the measurement of the E > 10 MeV proton flux by a satellite within the earth-moon system, the second digit represents the 30 MHz absorption measured by a sunlit polar riometer, and the third digit represents the response of a high latitude sea level neutron monitor. An "X" in the first digit indicates that not enough satellite data are available to make a determination of the maximum flux of protons greater than 10 MeV. A digit within parenthesis is provisional, based on partial data.

Column 15: Comments. This column contains various comments intended to be helpful to the reader. Examples are as follows:

a. Note 1 indicates that the Bailey (1964) VHF measurements converted to equivalent riometer absorption at Churchill are used for the onset time, time and value of maximum absorption, and the duration of the event.

b. Earlier onset times by measurements such as f-min or f-fix are given for general information.

c. Ground-level cosmic ray events are noted by "GLE". The earliest arrival time for relativistic protons is given.

d. Geomagnetic storms, the occurrence of which may affect the value of the maximum absorption, are noted. Sudden commencements are also given with the notation "SC".

e. A composite event where the onset time, maximum absorption, and duration of the event are from different locations or by different techniques (primarily because of incomplete data from each of the stations) are noted.

f. If there are other riometer data which indicate a higher maximum absorption than that given in the table proper, we note this difference by comments.

If a value is not known to us at the present time, a dash has been given in the table. Users of this table who can supply any of the missing data are requested to contact the authors.

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TABLE OF SIGNIFICANT (RIOMETER OBSERVED) SOLAR PROTON EVENTS
1955-1969

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours *	Location	PEC **	Comments
1.	1955	1	16	2230	VHF	--	--	----	~2	Churchill	48	Churchill	X 2 0	Note 1. F-min onset reported at ~20 UT.
2.	1956	2	23	04--	VHF	2	23	22--	13	Churchill	123	Churchill	X 3 4	Note 1. GLE; relativistic protons arrive at 0345±0005 UT.
3.	1956	3	10	09--	VHF	3	11	23--	3.5	Churchill	160	Churchill	X 2 0	Note 1.
4.	1956	8	31	1430	VHF	9	1	0430	4.9	Churchill	69	Churchill	X 2 1	Note 1. GLE; relativistic protons arrive at 1250±0015 UT.
5.	1956	11	13	20--	VHF	11	14	23--	5.4	Churchill	63	Churchill	X 3 0	Note 1. F-min onset reported at 14 UT.
6.	1957	1	20	15--	VHF	1	21	07--	4.1	Churchill	86	Churchill	X 2 0	Note 1.
7.	1957	4	3	1330	VHF	4	4	0330	3.9	Churchill	65	Churchill	X 2 0	Note 1. F-min onset reported at 1015 UT.
8.	1957	4	6	08--	VHF	4	6	20--	3.2	Churchill	66	Churchill	X 2 0	Note 1. F-min continues from 3 April for 13 days.
9.	1957	5	19	~02	Barrow Riometer	--	--	----	1	Barrow	>10	Barrow	X 1 0	
10.	1957	6	22	05--	VHF	6	24	01--	5.0	Churchill	115	Churchill	X 3 0	Note 1.
11.	1957	7	3	10--	VHF	7	3	22--	9.2	Churchill	52	Churchill	X 3 0	Note 1.
				10--	College Riometer	7	3	23--	6	College	>46	College		F-min onset reported at 0815 UT.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
12.	1957	7	24	2015	College Riometer	7	25	02--	2	College	>11	College	X 2 0	
13.	1957	8	9	16--	VHF	8	10	02--	3.1	Churchill	50	Churchill	X 2 0	Note 1. F-min onset reported at 15 UT on 9 August.
14.	1957	8	29	00--	VHF	8	29	07--	3.2	Churchill	C	Churchill	X 2 0	Note 1. F-min onset reported at 21 UT on 28 August.
15.	1957	8	29	13--	College Riometer	8	30	02--	9.0	College	C	College	X 3 0	SC at 1921 UT on 29 August.
				14--	VHF	8	30	02--	8.2	Churchill	C	Churchill		Note 1.
16.	1957	8	31	15--	VHF	9	1	03--	4.9	Churchill	46	Churchill	X 3 0	Note 1. F-min onset reported at 1415 UT. Gradual onset of geomagnetic storm at 12 UT on 31 August.
17.	1957	9	2	17--	VHF	9	3	02--	7.2	Churchill	46	Churchill	X 3 0	Note 1. F-min onset reported at 15 UT. College riometer observed 9 dB maximum absorption.
18.	1957	9	12	09--	VHF	9	12	----	0.5	College	24	-	X 1 0	Composite event. F-min onset reported at 02, 04, and 08 UT. SC at 0047 UT on 13 September.
19.	1957	9	21	17--	VHF	9	22	11--	5.1	Churchill	48	Churchill	X 3 0	Note 1. SC at 1005 UT on 21 September. SC at 1345 UT on 22 September.
20.	1957	9	26	21--	VHF	9	26	23--	2	College	>29	College	X 2 0	Composite event. Onset at College by 2315 UT.
21.	1957	10	20	21--	VHF	10	21	19--	7.8	Churchill	64	Churchill	X 3 0	Note 1. F-min onset reported at 17 UT.
22.	1957	11	5	02--	VHF	11	5	12--	2.6	Churchill	46	Churchill	X 2 0	Note 1. F-min onset reported at 23 UT on 4 November.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours *	Location	PEC **	Comments
23.	1958	2	10	06-- <07--	VHF College Riometer	2	10	20--	3.2 12	Churchill College	37 >30	Churchill College	X 3 0	Note 1. F-min onset reported at 05 UT.
24.	1958	3	23	15--	VHF	3	25	01--	3.2	Churchill	C	Churchill	X 2 0	Note 1.
25.	1958	3	25	1530	VHF	3	26	0430	10	Churchill	122	Churchill	X 3 0	Note 1. College riometer observed 12 dB maximum absorption. SC at 1540 UT on 25 March.
26.	1958	4	10	09--	VHF	4	10	18--	4.4	Churchill	68	Churchill	X 2 0	Note 1. Fort Yukon riometer observed 4.5 dB maximum absorption.
27.	1958	7	7	0130	Thule Riometer	7	8	0130	23.7	Churchill	96	Churchill	X 4 0	Composite event. Onset at Churchill at 0330 UT on 7 July. F-min onset reported at 01 UT. SC at 0748 UT on 8 July.
28.	1958	7	29	0405	Thule Riometer	7	29	06--	1.5	Thule	22	Thule	X 2 0	
29.	1958	8	16	06-- 06--	Thule Riometer VHF	8 8	16 16	- 22--	>15 12.1	Thule Churchill	56 71	Thule Churchill	X 4 0	 Note 1.
30.	1958	8	21	15--	Barrow Riometer	8	22	04--	3	Barrow	19	Barrow	X 2 0	F-min onset reported at 14 UT. SC at 0228 UT on 22 August.
31.	1958	8	22	1530	VHF	8	23	0230	10.6	Churchill	84	Churchill	X 3 0	Note 1. F-min onset reported at 14 UT.
32.	1958	8	26	01-- 0330	Thule Riometer VHF	8 8	26 26	20-- 2030	>13 16.6	Thule Churchill	93 70	Thule Churchill	X 4 0	 Note 1.
33.	1958	9	22	14--	VHF	9	23	12--	5.0	Churchill	80	Churchill	X 3 0	Note 1.
34.	1959	2	13	08--	VHF	2	13	20--	2.6	Churchill	74	Churchill	X 2 0	Note 1. Increase in geomagnetic storm at ~10 UT on 13 February.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
35.	1959	5	10	23--	Kiruna Riometer	5	12	04--	>17	Kiruna	221	Kiruna	X 4 0	
			11	0030	VHF	5	12	0230	22	Churchill	170	Churchill		Note 1.
36.	1959	6	13	1330	-	-	-	-	1.5	-	48	-	X 2 0	F-min onset reported at 08 UT.
37.	1959	7	10	04--	Kiruna Riometer	-	-	-	>17	Kiruna	C	Kiruna	X 4 0	SC at 1625 UT on 11 July.
				07--	VHF	7	11	12--	20	Churchill	C	Churchill		Note 1.
38.	1959	7	14	07--	Thule Riometer	7	15	02--	>15	Thule	-	-	X 4 0	
				0730	VHF	7	15	0330	23.7	Churchill	C	Churchill		Note 1.
39.	1959	7	16	22--	Kiruna Riometer	-	-	-	16	Kiruna	-	-	X 4 2	
			17	00--	VHF	7	17	10--	21.2	Churchill	67	Churchill		Note 1. GLE: Relativistic protons arrive at 0000±0200 UT on 17 July. SC at 1630 UT on 17 July.
40.	1959	8	18	~11	Thule Riometer	-	-	-	~1	Thule	~60	Thule	X 1 0	
41.	1960	1	12	03--	VHF	-	-	-	~2	Churchill	36	-	(0)2 0	Note 1. F-fix onset reported at 22 UT on 11 January.
42.	1960	3	30	20--	Thule Riometer	3	31	12--	5.5	Thule	C	Thule	X 3 0	Small absorption (~ 0.5 dB) at Thule until ~0730 UT on 31 March when absorption increases. Calibration problems at Thule at the end of March (some references give 7 dB maximum absorption). SC at ~09 UT on 31 March.
43.	1960	4	1	0945	Thule Riometer	4	1	17--	3	Thule	>86	Thule	1 2 0	

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
44.	1960	4	5	07--	VHF	4	5	23--	3.1	Churchill	55	Churchill	1 2 0	Note 1. F-min and F-fix onsets reported at ~04 UT.
45.	1960	4	28	0230	VHF	4	28	1430	2.5	Churchill	C	Churchill	(2)2 0	Note 1.
				05--	Thule Riometer	4	28	08--	3	Thule	C	Thule		
46.	1960	4	29	05--	VHF	4	30	08--	11.2	Churchill	36	Churchill	(1)3 0	Note 1.
				<06--	Thule Riometer	4	30	12--	14	Thule	114	Thule		F-fix onset reported at 02 UT.
47.	1960	5	4	1044	Thule Riometer	5	4	13--	5	Thule	>49	Thule	(1)2 4	GLE; relativistic protons arrive at 1030±0005 UT.
48.	1960	5	6	<1830	Thule Riometer	5	8	04--	>15	Thule	>110	Thule	(1)4 0	F-min and F-fix onset reported at 16 UT SC at 0421 UT on 8 May.
49.	1960	5	13	0620	Thule Riometer	5	13	13--	4.5	Thule	>65	Thule	(1)2 0	
50.	1960	9	3	05--	VHF	9	4	12--	2.7	Churchill	89	Churchill	2 2 1	Note 1. GLE; Relativistic protons arrive at 0200 ±0100 UT. SC at 0230 UT on 4 September.
51.	1960	9	26	07--	Churchill Riometer	-	-	-	~2	Churchill	-	-	(1)2 0	F-min onset reported at 06 UT; other riometer onsets reported at 1328 UT and 23-- UT.
52.	1960	11	12	14--	VHF	11	13	06--	21.2	Churchill	C	Churchill	4 4 4	Note 1. GLE; relativistic protons arrive at 1330±0005 UT. SC at 1348 UT on 12 November.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
53.	1960	11	15	0505	Kiruna Riometer	11	15	2210	>20	Kiruna	85	Kiruna	4 4 3	GLE; relativistic protons arrive at 0230±0005 UT. F-min onset reported at 0230 UT. SC at 1304 UT on 15 November.
54.	1960	11	21	02--	VHF	11	21	17--	3.0	Churchill	51	Churchill	(3)3 2	Note 1. GLE; relativistic protons arrive at 2100±0030 UT on 20 November.
				06--	Thule Riometer	-	-	-	5.0	Thule	-	-		F-min onset reported at 2300 UT on 20 November.
55.	1961	7	11	22--	College Riometer	7	12	05--	~1	College	C	College	X 1 0	F-min onset reported at 20 UT.
56.	1961	7	12	13--	Resolute Riometer	7	13	11--	17	Resolute	80	Resolute	(2)4 0	F-min onset reported at 1115 UT. SC at 1113 UT on 13 July.
57.	1961	7	18	<12--	College Riometer	7	18	20--	11	College	10	College	3 3 3	F-min onset reported at <10 UT. GLE; relativistic protons arrive at 1015±0005 UT. SC at 1123 UT on 18 July.
58.	1961	7	20	22--	College Riometer	7	21	14--	5	College	~24	College	(1)2 2	F-min onset reported at 17 UT. GLE; relativistic protons arrive at 1610±0005 UT. SC at 1550 UT on 20 July.
59.	1961	9	7	<10--	Fort Yukon Riometer	9	7	17--	1	Fort Yukon	~24	Fort Yukon	(0)1 0	
60.	1961	9	10	20--	Fort Yukon Riometer	9	11	21--	6.5	Fort Yukon	>72	Fort Yukon	(2)2 0	Spike to 8 dB on Fort Yukon riometer at 21 UT on 11 September.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
61.	1961	9	28	23--	Thule Riometer	9	30	~23--	3.3	Thule	77	College	2 2 0	SC at 2111 UT on 30 September.
62	1961	11	10	1530	Churchill Riometer	11	10	18--	1.5	Churchill	50	Churchill	1 2 0	
63.	1962	2	1	20--	Thule Riometer	2	2	14--	2.8	Thule	25	Thule	(1)2 0	
64.	1962	2	4	11--	Thule Riometer	2	4	16--	0.7	Thule	>12	Thule	0 1 0	
65.	1962	2	22	<07--	McMurdo Riometer	2	23	08--	0.7	McMurdo	>35	McMurdo	(0)1 0	No McMurdo riometer data available before 07 UT on 22 February. Some indication of very small absorption at Thule starting about 12 UT on 20 February.
66.	1962	10	23	1730	McMurdo Riometer	10	23	2320	0.9	McMurdo	16	McMurdo	(0)1 0	
67.	1963	2	9	1842	McMurdo Riometer	2	10	11--	2.4	Thule	148	McMurdo	-1 2 0	Composite event.
68.	1963	4	15	12--	McMurdo Riometer	4	16	00--	0.9	McMurdo	>48	McMurdo	1 1 0	
69.	1963	9	14	20--	McMurdo Riometer	9	15	01--	0.4	McMurdo	C	McMurdo	X 1 0	
70.	1963	9	15	<10--	Shepherd Bay Riometer	9	16	02--	0.5	McMurdo	>14	Shepherd Bay	X 1 0	Composite event.
71.	1963	9	16	<10--	Shepherd Bay Riometer	9	17	~10	0.8	Shepherd Bay	>62	Shepherd Bay	X 1 0	
72.	1963	9	21	0020	Shepherd Bay Riometer	9	21	18--	4	Shepherd Bay	>84	Shepherd Bay	1 2 0	
73.	1963	9	26	0730	VHF	9	26	1530	4.6	Churchill	>89	Churchill	(1)3 0	Note 1.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
74.	1964	3	16	1730	McMurdo Riometer	3	17	00--	0.2	McMurdo	>15	McMurdo	0 1 0	0.2 dB is hourly average absorption; some spikes to 0.3 dB.
75.	1965	2	5	1850	Shepherd Bay Riometer	2	6	01--	1.3	McMurdo	>77	McMurdo	1 1 0	1.3 dB is hourly average absorption; spike to 1.8 dB.
76.	1966	3	24	0250±17	McMurdo Riometer	3	24	04--	1.6	McMurdo	38	McMurdo	1 2 0	
77.	1966	7	7	0120	Shepherd Bay Riometer	7	7	12--	2.1	Thule	47	Shepherd Bay	1 2 1	Composite event. GLE; relativistic protons arrive at 0042±0002 UT. Gradual onset of geomagnetic storm at ~02 UT on 8 July; SC geomagnetic storm at 2102 UT on 8 July.
78.	1966	8	28	~17	Shepherd Bay Riometer	-	-	-	4.0	Shepherd Bay	-	-	1 2 0	F-min onset reported at 16 UT on 28 August.
				19--	Thule Riometer	8	30	01--	2.4	Thule	56	Thule		SC at 1315 UT on 29 August.
79.	1966	9	2	06--	McMurdo Riometer	9	2	15--	14.0	Thule	~168	McMurdo	2 3 0	Composite event. SC at 0823 UT on 2 September.
80.	1966	9	14	-	-	9	15	02--	1.2	Shepherd Bay	-	-	0 1 0	F-min onset reported at 23 UT on 14 September. Maximum absorption near local sunset.
81.	1967	1	28	04--	McMurdo Riometer	1	28	07--	0.5	McMurdo	C	McMurdo	0 1 1	GLE; relativistic protons arrive at 0302±0003 UT. Maximum riometer absorption of 0.5 dB continues into next event.
82.	1967	1	28	0915	McMurdo Riometer	1	28	1820	7.0	McMurdo	131	McMurdo	1 3 3	GLE; relativistic protons arrive at 0810±0010 UT.
83.	1967	2	2	20--	McMurdo	2	3	06--	2.6	McMurdo	130	McMurdo	1 2 0	

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION				
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**		Comments
84.	1967	2	13	-	McMurdo Riometer	2	16	02--	0.5	McMurdo	-	-	-1	1 0	VLF onset at Kiruna at 1850 UT.
85.	1967	3	11	19--	Thule Riometer	3	12	02--	1.6	McMurdo	25	Thule	0	2 0	
86.	1967	5	23	2330	Shepherd Bay Riometer	5	25	13--	11.0	Shepherd Bay	C	Shepherd Bay	3	3 0	F-min onset reported at 20 UT on 23 May. SC at 1726 UT on 24 May.
87.	1967	5	28	06--	Thule Riometer	5	28	09--	4.1	Thule	59	Thule	2	2 0	F-min onset reported at 03 UT on 28 May.
				0630	Shepherd Bay Riometer	5	28	08--	3.7	Shepherd Bay	60	Shepherd Bay			SC at 1425 UT on 30 May.
88.	1967	6	6	09--	Thule Riometer	6	7	02--	1.8	Thule	61	Thule	1	2 0	F-min onset reported at 08 UT on 6 June.
89.	1967	6	12	-	Shepherd Bay Riometer	6	15	16--	0.3	Shepherd Bay	>78	Shepherd Bay	0	1 0	
90.	1967	7	5	-	Shepherd Bay Riometer	7	6	22--	0.3	Shepherd Bay	-	-	-1	1 0	
91.	1967	9	18	-	McMurdo Riometer	9	18	18--	0.6	McMurdo	-	-	-2	1 0	F-min onset reported at 10 UT on 18 September.
92.	1967	9	20	-	McMurdo Riometer	9	20	18--	0.8	McMurdo	-	-	-1	1 0	Geomagnetic storm in progress (SC at 1957 UT on 19 September).
93.	1967	11	2	-	McMurdo Riometer	11	2	18--	0.9	McMurdo	-	-	0	1 0	F-min onset reported at 09 UT on 2 November. SC at 0914 UT on 3 November.
94.	1967	11	7	-	McMurdo Riometer	11	7	06--	0.5	McMurdo	-	-	-1	1 0	
95.	1967	11	13	-	McMurdo Riometer	11	15	03--	0.5	McMurdo	-	-	0	1 0	F-min onset reported at 00 UT on 13 November.
96.	1967	12	3	-	McMurdo Riometer	12	3	14--	1.8	McMurdo	-	-	1	2 0	F-min onset reported at 10 UT on 3 December.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
97.	1967	12	16	-	McMurdo Riometer	12	16	17--	0.8	McMurdo	-	-	0 1 0	F-min onset reported at 07 UT on 16 December.
98.	1967	12	17	-	McMurdo Riometer	12	17	21--	0.7	McMurdo	-	-	0 1 0	F-min PCA continued from previous event.
99.	1968	1	11	1840	McMurdo Riometer	-	-	-	-	-	C	McMurdo	-1 1 0	PCA continues to rise to next event.
100.	1968	1	12	-	McMurdo Riometer	1	12	03--	0.7	McMurdo	-	-	0 1 0	
101	1968	2	8	15--	McMurdo Riometer	2	8	17--	0.6	McMurdo	-	-	0 1 0	
102.	1968	2	17	-	McMurdo Riometer	2	17	09--	0.4	McMurdo	-	-	0 1 0	F-min onset reported at 07 UT on 17 February.
103.	1968	4	26	~1630	Shepherd Bay Riometer	4	26	1815	0.5	Shepherd Bay	-	-	0 1 0	
104.	1968	6	9	10--	Thule Riometer	6	10	08--	6.5	Thule	63	Thule	2 3 0	F-min onset reported at 09 UT on 9 June. SC at 2154 UT on 10 June.
105.	1968	7	7	-	Shepherd Bay Riometer	7	8	18--	0.4	Shepherd Bay	C	Shepherd Bay	0 1 0	F-min onset reported at 09 UT on 7 July.
106.	1968	7	9	09--	Shepherd Bay Riometer	7	11	03--	1.1	Shepherd Bay	C	Shepherd Bay	1 1 0	SC at 2154 UT on 9 July.
107.	1968	7	12	06--	Shepherd Bay Riometer	7	12	11--	0.9	Shepherd Bay	C	Shepherd Bay	0 1 0	
108.	1968	7	12	1930	Shepherd Bay Riometer	7	13	19--	3.0	Shepherd Bay	-	-	1 2 0	SC at 1612 UT on 13 July.
109.	1968	9	26	<08--	McMurdo Riometer	9	26	23--	0.8	McMurdo	-	-	1 1 0	Response may be principally due to electrons.
110.	1968	9	28	11--	McMurdo Riometer	9	28	21--	1.2	McMurdo	-	-	1 1 0	

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
111.	1968	9	29	1700	McMurdo Riometer	9	29	23--	1.7	McMurdo	-	-	1 2 1	GLE; relativistic protons arrive at 1645±0003 UT on 29 September SC at 0018 UT on 2 October.
112.	1968	10	4	0120	McMurdo Riometer	10	4	15--	1.6	McMurdo	-	-	1 2 0	SC at 0628 UT on 6 October.
113.	1968	10	31	05--	McMurdo Riometer	10	31	17--	5.5	McMurdo	C	McMurdo	2 3 0	F-min onset reported at 00 UT on 31 October.
114.	1968	11	1	12--	McMurdo Riometer	11	2	18--	4	McMurdo	-	-	2 3 0	SC at 0916 UT on 1 November (associated with flare of previous event).
				14--	Thule Riometer	11	2	19--	2.5	Thule	40	Thule		
115.	1968	11	4	0615	McMurdo Riometer	11	4	09--	1.6	McMurdo	-	-	1 2 0	
116.	1968	11	18	1045	McMurdo Riometer	11	18	14--	12.5	McMurdo	53	Thule	2 3 3	Composite event. Onset at Thule at 14 UT but Thule in darkness. GLE; relativistic protons arrive at 1035±0005 UT on 18 November. SC at 0904 UT on 20 November.
117.	1968	12	3	19--	McMurdo Riometer	-	-	-			C	McMurdo	1 2 0	
118.	1968	12	5	-	McMurdo Riometer	12	6	05--	4.7	McMurdo	-	-	2 3 0	SC at 0633 UT on 5 December.
119.	1969	1	24	<14	Thule Riometer	1	24	17--	1.4	McMurdo	>24	Thule	0 1 0	Composite event. F-min onset reported at 12 UT.
120.	1969	2	25	12--	Thule Riometer	2	25	15--	2.1	Thule	C	Thule	1 2 3	GLE; relativistic protons arrive at 0915±0005 UT. VLF onset reported at 0928 UT. F-min onset reported at 10 UT.

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION			
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**	Comments
121.	1969	2	26	-	-	2	26	-	1.3	McMurdo	C	McMurdo	1 1 0	
						2	26	17--	0.9	Thule	C	Thule		
122.	1969	2	27	15--	Thule Riometer	2	27	17--	1.1	Thule	C	Thule	1 1 0	
						2	27	(17--)	1.3	McMurdo	-	-		Two maxima at McMurdo.
								(22--)	1.3	McMurdo	-	-		
123.	1969	2	28	13--	Thule Riometer	2	28	18--	1.0	Thule	>33	Thule	1 1 0	
						2	28	-	1.1	McMurdo	-	-		
124.	1969	3	12	-	McMurdo Riometer	3	12	22--	0.7	McMurdo	-	-	0 1 0	
125.	1969	3	21	-	McMurdo Riometer	3	(21	21--)	0.8	McMurdo	-	-	0 1 0	F-min onset reported at 02 UT. Two maxima at McMurdo.
							(22	04--)						
126.	1969	3	30	11	Thule Riometer	3	30	19--	1.3	Thule	>120	Thule	1 1 2	VLF onset reported at 04 UT on 30 March.
						3	31	03--	1.4	Shepherd Bay	-	-		GLE; relativistic protons arrive at 0400±0100 UT on 30 March.
127.	1969	4	11	13--	Thule Riometer	4	13	08-24	>16	Thule	>240	Thule	3 3 0	VLF onset reported at 09 UT on 11 April. F-min onset reported at 11 UT on 11 April. Thule riometer saturated 08-24 UT on 13 April.
128.	1969	5	13	-	-	5	15	00--	1.2	Shepherd Bay	-	-	1 1 0	Geomagnetic storm 18 UT on 12 May. SC at 1930 UT on 14 May.
129.	1969	6	7	2141	Shepherd Bay Riometer	6	8	18--	1.4	Shepherd Bay	>120	Shepherd Bay	1 1 0	

	DATE AND ONSET TIME					MAXIMUM OF ABSORPTION EVENT					DURATION				
No.	Year	Month	Day	Onset Time (UT)	Location and/or Technique	Month	Day	Time (UT)	Absorption (dB)	Location	Hours*	Location	PEC**		Comments
130.	1969	9	25	~10	Shepherd Bay Riometer	9	25	13--	0.7	Shepherd Bay	> 12	Shepherd Bay	1	1 0	
131.	1969	9	27	~08	-	9	27	10--	0.3	McMurdo	C	McMurdo	-1	1 0	
132.	1969	9	27	22--	McMurdo Riometer	9	28	03--	1.7	McMurdo	48	Shepherd Bay /McMurdo	1	2 0	Duration taken from McMurdo onset and Shepherd Bay end. SC at 2125 UT on 27 September. SC at 0453 UT on 29 September. There is a spike of ~3.4 dB in the McMurdo riometer data at ~05 UT on 29 September probably associated with the SC at 0453 UT on that day.
133.	1969	10	14	-	McMurdo Riometer	10	14	-	0.4	McMurdo	-	-	0	1 0	
134.	1969	11	2	1048±01	Dumont D'Urville Riometer	11	2	1630	13	Dumont D'Urville	-	-	3	3 0	Spike on McMurdo riometer extends to 14.5 dB; hourly average is 12 dB.
				1050±05	McMurdo Riometer	11	2	17--	12	McMurdo	C	McMurdo			
135.	1969	11	7	12--	McMurdo Riometer	11	8	07--	1.4	McMurdo	40	McMurdo	0	1 0	F-min onset reported 09 UT on 7 November.
136.	1969	11	24	-	-	11	24	-	0.7	McMurdo	-	-	0	1 0	F-min onset reported 10 UT on 24 November.
137.	1969	12	18	-	-	12	18	-	0.6	McMurdo	-	-	0	1 0	F-min onset reported 20 UT on 18 December.
138.	1969	12	20	-	-	12	20	-	1.3	McMurdo	-	-	0	1 0	F-min onset reported 01 UT on 20 December.
139.	1969	12	30	-	-	12	30	-	0.4	McMurdo	-	-	0	1 0	

* Duration. "C" indicates that absorption continued into the next event.

** PEC. Proton Event Classification (Smart and Shea, 1971).

Note 1. Computed absorption that would have been observed by a riometer at Fort Churchill, Canada. These values have been derived from VHF data by Bailey (1964).